Urban transport & potential mitigation options for Delhi

Final project report

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Project Description

Comprehensive vehicle inspection program focusing on the emissions performance of vehicles An effective inspection regime for in-use vehicles coupled with a penalty regime would result in improved maintenance and therefore better overall performance, including fuel efficiency. This would directly impact vehicle GHG emissions, while also improving local air quality

Project Costs & CO_2 savings

US$ million	CO_2 savings (kilotons)	Cost of CO_2 (US$ per tonne)
94 36	2568-12325	3 48-12.44

CDM: Emissions Monitoring & Verification protocol

To determine the extent of GHG reduction from a given vehicle the important factors are.

a) Design fuel efficiency of the vehicle and the expected fuel efficiency given the age of the vehicle, if the vehicle is maintained as per present practices.
b) Improvement in fuel efficiency of the vehicle due to checking and maintenance at the proposed I&M centre and the longevity of such improvement of efficiency.

The factor a) identified above will be predetermined for a variety of sizes, makes, models and age of the vehicles. The factor b) will also be predetermined for the range of vehicles. The actual reduction achieved due to the project will be determined based on the factors a) and b) and the actual number of visits by different types of vehicles in the proposed I&M centres.

Transport demand option

Project description

Augmenting bus fleet, restricting personal vehicles, car-sharing; + possible use of fuel cell vehicles

Costs and CO_2 savings

Scenario	Actions	CO_2 saving (ktonne) in 2008	Cumulative CO_2 saving (ktonne), 2003-2012	Total capital costs ($M)	Discounted cost/tonne CO_2 saved over 2003-2012
I	Car users switch from gasoline vehicles to CNG buses	1015	7105	$275 (Discounted costs $226)	$32
II	I + increased public transport use in non-peak times + car-sharing	1440	10080	$330 (Discounted costs $270)	$27
III	II + use of fuel cell vehicles	1450	10150	$360 (Discounted costs: $295)	$29

CDM: Monitoring and verification

A range of advantages to the combined approach; easier baseline calculation and monitoring data collection, as well as sub-sector technical baselines. The combined effects

of the three measures can be aggregated into a single function to demonstrate CO_2 reduction potential.
However, a range of technical challenges; including data deficiencies on fuel and vehicle use, uncertain data due to differences between laboratory/test conditions and experienced reality, and forecasting uncertainties due to the complex nature of the transport sector.

Conclusions

Inspection & maintenance is less expensive than the combined option. However, the two must be seen together. I&M is a valuable short-term project, while the combined, traffic management, option is a longer-term project. The I&M option uses technology as a short-term fix, while the combined traffic management option tackles more fundamental problems which policymakers will need to address in the medium-term It therefore uses technology in a more ambitious way, showing leadership and vision.

It would be worth examining how carbon financing from CDM projects can be attributed to other benefits, such as reduced air pollution in the city. These benefits accrue over a longer time than the accounting period used for CDM purposes

Inspection and Maintenance option: Overall summary

Project Description

A comprehensive vehicle inspection program focusing on the emissions performance of vehicles is being suggested for Delhi. It is envisaged that an effective inspection regime for in use vehicles coupled with a penalty regime would imply an improved maintenance of these vehicles. Thus the performance of all vehicles would improve on all counts, including fuel efficiency. This improvement would directly impact the GHG emissions from the vehicle population, while at the same time improve the local air quality also. The project would be limited to the municipal boundaries of Delhi, termed as the National Capital Territory of Delhi to reduce the institutional complexity of the proposed project while at the same time minimizing costs by using secondary data to estimate the baseline.

Emissions Baseline Technology

Vehicular emissions for a given period have been estimated as the product of (1) emissions per unit of fuel (2) fuel consumed per kilometer and (3) total PKM (passenger-kilometer). Based on this generalization, a baseline for transport sector in Delhi based on existing emissions, taking into account future changes including emissions legislation, increase in demand, and improvements in technology has been estimated It is assumed that the present trend of registration of vehicles adjusted with assumed attrition values for different modes and penetration of energy efficient modes would continue in Delhi, and that modal split pattern, and occupancy/load factors remain unchanged. The baseline incorporates improvements both by way of improvements in fuel efficiency due to better technology and emissions by way of increasingly stringent emissions standards

Project Costs

The cost estimates for all options have been prepared for a 10 year project period, 2005 to 2015, given that this is the maximum emissions crediting period for a CDM project without revising the baseline[a] The investment was assumed to take place at two time points, 2005 and 2010, instead of just once at the beginning of the project. The discount rate for this projects was assumed to be 12% All calculations have been carried out assuming an exchange rate of 1 US dollar equals 50 Indian Rupees A summary of the results is presented below.

Project cost (US$ million)	94.36
NPV of project (US$ million)	-42 85
CO_2 savings (kilo tonnes)	2568-12325
Cost of CO_2 (US$ per tonne)	3.48-12 44
Impact of CDM on IRR (Low GHG reduction scenario)	-16% to -6%
Impact of CDM on IRR (High GHG reduction scenario)	-16% to -3%

Emissions Monitoring & Verification protocol

To determine the extent of GHG reduction from a given vehicle the factors, which are important, are as follows

c) The design fuel efficiency of the vehicle and the expected fuel efficiency given the age of the vehicle, if the vehicle is maintained as per the present practices.
d) The improvement in the fuel efficiency of the vehicle due to checking and maintenance at the proposed I&M centre and the longevity of such improvement of efficiency.

The factor a) identified above will be predetermined for a variety of sizes, makes, models and age of the vehicles The factor b) will also be predetermined for the range of vehicles The actual reduction achieved due to the project will be determined based on the factors a) and b) and the actual number of visits by different types of vehicles in the proposed I& M centres.

[a] Marrakesh Accords Decision 17/CP 7

Transport Demand Management option: Overall summary

Description of the option: Interaction Matrix

Option description	Activity	Modal share	Vehicle energy intensity	Fuel mix
Augmenting New Delhi bus fleet	Lower total vehicle-km as car users shift to bus	Greater share for public transport	Better vehicle technology, more energy efficient	CNG offers better air quality benefits
Restricting use of personal vehicles	Significant car use restraint; depends on costs, time of day, enforcement	Favours high passenger load factor modes (i e bus and taxi)	Little effect unless permits small vehicles selectively	Little effect unless cleaner fuels exempt
Car-sharing	Lower absolute number of vehicles, reduced total vehicle-km	Shifts from other travel modes	Little effect unless higher efficiency vehicles used	Little effect unless cleaner fuels used
Fuel-cell vehicles	Little direct effect	Little direct effect	Encourages better vehicle energy efficiency	Potentially large effect

Probable costs and CO_2 savings

Scenario	Actions	CO_2 saving (ktonne) in 2008	Cumulative CO_2 saving (ktonne), 2003-2012	Total capital costs ($M)	Discounted cost/tonne CO_2 saved over 2003-2012
I	Car users switch from gasoline vehicles to CNG buses	1015	7105	$275 (Discounted costs $226)	$32
II	I + increased public transport use in non-peak times + car-sharing	1440	10080	$330 (Discounted costs $270)	$27
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Savings and costs calculated on a crediting period, 2003-2012
Assumption: measures are fully implemented by 2008, savings increasing linearly up to the maximum, and thereafter the maximum achieved in each year from 2008 onwards
Income from bus passengers or parking fees is ignored, as it is assumed to equal operating and fuel costs for the additional buses and the traffic management measures, and therefore have a zero net effect on the project economics
All capital costs are assumed to be linear (2003-2008), and are discounted at 10%

CDM credit feasibility
Positive:

- Controlled fleet, more reliable information on fuel used and kilometres travelled. Baseline calculation and monitoring data collection and analysis are much easier;
- Sub-sector technical baselines can be estimated using base year emissions data and projections of future emissions levels based on technological parameters;
- Proposed combined option includes elements of mode shifting, affecting emissions per person-kilometre. Expressing baseline and monitoring in terms of CO_2 reduction per person-kilometre allows combined effects of the three measures to be aggregated into a single function to demonstrate the CO_2 reduction potential

Negative (technical challenges):

- Data deficiencies, including amounts of fuel used by transport, vehicle fuel efficiencies, kilometres travelled, types of trip purpose, types of road etc;
- Data uncertainty, as fuel consumption data collected under laboratory or test conditions may not reflect the actual on the road fuel consumption;
- Forecasting uncertainties, given that the transport sector is very complex.

Introduction

The transport sector in developing countries accounts for a large share of greenhouse gas (GHG) emissions (e.g 10% of total emissions in Asia), with relatively big variations between countries Transport contributes to climate change, air pollution and congestion. Because of the strong growth the transport sector in these countries (e g in India the transport share of total emissions is projected to grow by about 65% from 1990 to 2010), projects in this sector could bring big benefits in terms of emissions reductions. Governments are looking at ways to develop projects based on renewable energy sources, energy efficiency improvements and demand side management in the fields of energy and transport.

India is now the world's second most populous country, with more than one billion inhabitants. Nearly one-third of the total population lives in cities India is the world's sixth-largest and second-fastest growing producer of greenhouse gases Indian cities have made several efforts on urban air quality improvement, but less so on CO_2 emissions. Programmes dealing with air quality generally do not pay any attention to CO_2 – the main GHG produced from the use of fossil fuels in the transport sector – and typically not to methane and nitrous oxides either – the three most important pollutants in terms of global climate change.

Transportation in India, which is predominantly road based, is one of the most rapidly rising sources of GHG emissions, increasing faster than Gross Domestic Product Authorities in India tend to place a low priority on the externalities associated with GHG damage, and are more immediately concerned with congestion, air pollution and safety. Control programmes to protect the global and local environments are not yet in place. The strategic option is to align initiatives to restrain GHG emissions within overall, necessary, transport reform. The key question that arises here is to what kind of strategies to adopt so that local and global benefits can be achieved simultaneously

Little attention has been paid to the question of climate change in the planning and organisation of urban transport. Furthermore, various factors are lacking· information about promising measures aimed at reducing GHG emissions, knowledge of how to draw up appropriate plans of action and strategies, structures for implementing measures on a cross-institution basis, and understanding of the need to involve citizens and affected groups in the planning processes

Few people have recognised that in many cases contributions to global climate protection can be achieved in parallel with reductions in local environmental pollution without additional expenditure if urban transport is organised differently; thus achieving a double dividend.

This project has identified the potential for implementing policy and other measures to achieve urban transport and climate change benefits. These include both policy initiatives that are a mandate of the governments in the region and their various instrumentalities, and also business initiatives where the non-government sector, including the private sector, can provide inputs in terms of investment and managerial support This list was based on an initial assessment of the potential for GHG mitigation as well as the impact on local environment in the specific context of Delhi.

The feasibility of implementation of the projects being suggested was also taken into account. Finally, another important criteria for the opportunities identified was the potential for replicability to ensure that the activities undertaken after this study for implementing these catalyse action in other urban locations also The results of this project could be

used subsequently to determine the possibility of urban transport projects that would result in credits under a future CDM or technology transfer system. In practice, the project forms the pre-feasibility phase of CDM project/s in New Delhi, focusing on identifying a short list of options.

The project is carried out by a European NGO (T&E) and an Indian research institute (TERI), in what can be called a north-south co-operation. Ford Motor Company, which funded the project, has been an active participant in the preparation and the meetings and was a member of the advisory committee Ford's main interest in this project has been to contribute to the knowledge of transport and climate change issues and opportunities in India

The clean development mechanism

CDM (Clean Development Mechanism) is a market-based mechanism that was introduced under the Kyoto Protocol to the UNFCCC (United Nations Framework Convention on Climate Change). Under this Protocol, Annex I countries[a] are required to reduce their GHG (greenhouse gas) emissions to below their 1990 levels. CDM enables these countries to meet their reduction commitments in a flexible and cost-effective manner It allows public or private sector entities in Annex I countries to invest in GHG mitigation projects in developing countries. In return, the investing parties receive credits or CERs (Certified Emission Reductions), which they can use to meet their targets under the Kyoto Protocol While investors profit from CDM projects by obtaining GHG emission reductions at costs lower than those in their own countries, the gains to the host parties are in the form of investment, better technology, and local sustainable development benefits.

Projects starting in the year 2000 are eligible for the CDM if they lead to 'real, measurable, and long-term' GHG reductions, which are additional to any that would occur in the absence of the CDM project. Further, such projects should not lead to diversion of official development assistance or the financial obligations of Annex I countries.

There are no known instances of CDM projects in the transport sector, although there is now substantial literature on the climate change implications of the transport sector The rapid growth in GHG emissions in this sector provides a significant opportunity for mitigation In 1999, the transport sector was the source of approximately 24 percent of global energy-related carbon dioxide emissions. Worldwide, emissions of carbon dioxide from the transport sector are projected to grow at the rate of 2 5 percent each year to 2020. In contrast, the growth rate of greenhouse gas emissions from other major sectors is projected to be lower (OECD 2001)[b].

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[a] Annex I of the UNFCCC lists developed countries and economies in transition.

[b] An Initial View on Methodologies for Emission Baselines: Case Study on Transport. OECD and IEA Information Paper. Deborah Salon, International Energy Agency. Paris, October, 2001

Project history

The first action undertaken within the scope of the project was a literature review. This outlined urban transport and mitigation options for New Delhi, as well as an overview of urban transport and the clean development mechanism in developing countries

On the basis of the review, an 'options' document was prepared, setting out eleven options for reducing CO_2 emissions from New Delhi transport[a]. These options are listed below in Table 1 They were then presented to a national stakeholder seminar, held in New Delhi on 22 April 2002, together with a set of rough costs/CO_2 savings estimates for each option. These estimates were done to provide an indication of the likely levels of investment costs and CO_2 savings

Table 1 Mitigation opportunities in the transport sector: a list of the projects[b].

Category	Option
Transport demand management	▪ Augmentation in the public transport (bus) fleet in Delhi ▪ Restricting the use of personal vehicles ▪ Promoting integrated land use and transport planning ▪ Car-sharing in Delhi
Improving environmental performance of vehicles	▪ Inspection and maintenance for in use vehicles
Pilot projects to establish feasibility of alternative technologies	▪ Feasibility & logistical requirements for running a fleet of BOVs (battery operated vehicles) ▪ Feasibility & logistical requirements for running a fleet of fuel cell vehicles
Traffic management initiatives	▪ Park and ride schemes ▪ Infrastructure for non motorised transport ▪ Priority to public transport ▪ Parking management of a commercial area on a major arterial road

Outcome of stakeholder consultations

The seminar on urban transport in New Delhi discussed the mitigation opportunities listed above in detail

The consensus was that the transport field is too complex for only one transport demand management option to have a real effect if implemented Each individual option involves a series of trade-offs, and the stakeholders felt a series of jointly-implemented options would be needed for there to be real benefits.

A number of options were initially discussed as being potentially worthwhile elements of a cluster of transport demand management options, but later discarded. There are two sets of reasons for why this happened Firstly, the greater the number of individual components, the more complicated the overall system, and the more difficult it is to measure and verify This meant that the number of options in the cluster had to kept as low as possible. Secondly, each rejected option had an individual problem that caused it to be rejected All traffic management options are by definition site-specific. By contrast, the other options in transport demand management and technology initiatives are applicable city-wide. This, combined with the fact that traffic management options are difficult to

[a] The 11 options are in four broad categories transport demand management; technology based options, improving environmental performance of vehicles; traffic management initiatives

[b] The detailed description of these measures was presented in the earlier report titled Opportunities for GHG mitigation in urban transport sector in Delhi

monitor, meant these were unsuitable for inclusion. These include options such as NMT (non-motorised transport) infrastructure and priority to public transport that could be a powerful option, but it would be extremely difficult to monitor and would require a site-specific baseline In combination with the other options, it would simply be too complicated to be feasible.

In addition to transport demand management, there was agreement that inspection and maintenance would be a good short term option for reducing emissions of CO_2 and conventional air pollutants from the transport sector in Delhi.

The workshop discussed each of these options and participants expressed clearly that a package of measures would be needed to reduce CO_2 emissions and improve up New Delhi's air quality

For these reasons, two options were shortlisted in the wake of the seminar One is a conglomeration of transport demand management options and is clearly a longer-term initiative The second, Inspection & Maintenance of in-use vehicles, is a shorter term option Some additional work was then done on estimating CO_2 emissions reduction potential and investment costs for these shortlisted options. The figures can only be indicative at this stage, and the level of knowledge available for each option is different

In addition to numerous partner meetings, two workshops were planned as part of the consultation process in the project: a national stakeholder workshop, held in New Delhi in April 2002, and an international experts' seminar, to be held at the CoP8 in New Delhi, 2002, at which the final project report and outcome of the research are to be presented

This final report discusses the two shortlisted options in detail.

Inspection & Maintenance option

Improving environmental performance of in use vehicles

India has witnessed a rapid increase in its vehicle population over the last four decades. From a 'mere' 3 million vehicles in the 1960s, the number went up to over 35 million by 2000. This growth is expected to continue in the coming years. Large cities face a higher concentration of motor vehicles than the smaller towns.

Given the rapid rise in the number of motor vehicles in cities, growing fuel consumption and deteriorating air quality are increasingly important issues To mitigate the adverse effects of auto emissions, more stringent emission norms (Bharat Stage I and Bharat Stage II, similar to EURO I and EURO II) are being introduced for new vehicles. However, as the improvement in emission norms for new vehicles has not been mirrored in improvement in emissions performance of in use vehicles, these only help to control the emissions from new vehicles and have no effect on the significant emissions from the vehicles already on the roads. In metropolitan cities like Delhi, a large percentage of such vehicles are old vehicles, and do not meet the present stringent emission norms. Therefore, emission norms should also be prescribed for the nearly 3 million in-use vehicles in Delhi. Inspection and maintenance is therefore a mitigation opportunity in the transport sector.

An effective inspection and maintenance (I&M) programme has been used successfully to improve the environmental performance of the vehicle fleet in other countries in South Asia. Apart from local emissions, there is also potential for GHG mitigation, arising from improvements in fuel efficiency of better maintained in-use vehicles. Das et al. (2001)[a] report that enforcement of the existing inspection regime in Delhi could result in an improvement in fuel efficiency of 10-20% in the case of two wheelers They also report studies by ARAI (Automotive Research Association India) documenting improvements of 15% in two wheelers In case of any emission norms prescribed for the "in-use" vehicles, it is important that there be a mechanism for certifying that the prescribed norms are met consistently. Therefore, there is need for a number of inspection centres in Indian cities, complemented by an effective institutional and regulatory framework for managing them. This is the basis of the proposed CDM project.

Lessons from international experience

A literature review of selected countries with similar transportation issues such as Malaysia, Hong Kong, China and Philippines, has been carried out to identify essential issues in the design of an appropriate inspection system[b]. In most countries, a total road-worthiness test is carried out for granting a vehicles fitness certificate. It covers both safety and environmental aspects. For example, the following tests are carried out in Japan:

- Environment parameters: CO, HC emissions
- Safety parameters
- Visual inspection

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[a] Prospects of inspection and maintenance of two wheelers in India. Sujit Das, Rick Schmoyer, Glen Harrison, and Karl Hausker. Energy Division. Oak Ridge National Laboratory.

[b] Faiz A. Overview of Inspection and Maintenance Policy and Programs. Paper presented at GITE Regional Workshop on Transport Sector Inspection and Maintenance Policy in Asia. [10-12 December, 2001, Bangkok, Thailand] organised by UNDESA, UNESCAP and JARI: GTZ, 2001. Inspection and Maintenance and Roadworthiness Program for Surabaya. GTZ Sustainable Urban Transport Project, Indonesia pp.50

International experience has shown that "test only centres" such as in Malaysia and the UK, run by a single contractor have produced best results. Test and repair garages may be convenient for vehicle owners and easy to set up for the government, but in practice are highly flawed, as has been revealed in Mexico. Ten 5-lane test-only centres have the same test capacity as 120 test and repair centres and are clearly easier to control They facilitate the adoption of new technology and generate more uniform results between centres.

An I&M program needs to be mandatory· experience has shown that voluntary programs are not successful if the owners have to pay a fee. In addition, the program should be framed within a national regulatory framework with its implementation being done by the state government or the local government.

There is a variety of emission test procedures followed for in-use vehicle emission control worldwide. These can be classified into the following:

1. The I&M Test Procedure for Emission Checking World-wide, which includes:
   - Tailpipe emission measurement
   - Evaporative system effectiveness
2. Remote Sensing
3. On-board Diagnostic System Check as a part of vehicle I&M programme

A properly regulated and enforced vehicle inspection and maintenance program could lead to a number of local and global benefits. JARI reports fuel efficiency improvements of 24%[a] Das et al. (2001) report an improvement of only 5% in the US following the US EPA IM240 program. The EPA in its regulatory impact analysis estimated improvements to be 12.6%. While the JARI results are considered as optimistic, these can be nevertheless taken as indicative of the upper bound of improvements. Similarly, the US results reported by Das et al. (2001) can be taken as the lower bound.

In addition, there is a reduction in local pollutants of about 20-27%, as in Kathmandu[b]. Further, studies have shown fewer accidents in countries where an I&M program was implemented successfully. Apart from these benefits, which are external to the vehicle user, there are cost savings due to proper maintenance of vehicles

Designing an Inspection and Maintenance program

The following is a description of the proposed mitigation opportunity as a CDM project in Delhi

Description of the project

The CDM project would involve an inspection regime for in use vehicles to bring about improvements in vehicle maintenance, and hence fuel efficiency. This improvement would directly influence the GHG emissions from the vehicle population, while at the same time improving local air quality. The scope of the proposed projects is determined by the availability of secondary data. Given that information on fuel efficiency improvements arising from effective I&M is not available for each mode and vehicle technology, a range of the potential GHG savings is presented for the entire vehicle fleet based on the results reported by JARI (2001) and Das et al. (2001).

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[a] Inspection and Maintenance System in Japan. Keiko Hirota and Kiyoyuki Minato. JARI (2001)
[b] Gronskei 1996 Urban air quality management strategy in Asia: Kathmandu valley report. K E Gronskei. Washington D C. 1996 pp 156.

A Centralised comprehensive vehicle inspection program focusing on environmental performance of a vehicle is suggested. It should have "test only centres", run by a single contractor. In addition, a well functioning audit and quality assurance system is crucial for acceptance and success The Delhi Government's Transport Department would have to set up a team of qualified personnel to audit centres' performance The team would check for the proper presence of necessary equipment and other infrastructure, and the inspection procedure being followed

A penalty system would need to be activated for the service centres, based on the UK model; where for every type of offence committed a number of penalty points are awarded. After a centre accumulates a given number of penalty points, its license is revoked, thus enabling a more transparent form of working of the inspection centre and auditing process.

An effective maintenance program is also an essential part of the overall strategy. The vehicle manufacturers would need to authorise these repair centres. This would ensure that the owners get good repair and maintenance of their vehicles. In addition, vehicle manufacturers should give vehicle owners a detailed manual with guidelines and tips on maintaining roadworthiness.

Project boundary

The project would be limited to the municipal boundaries of Delhi, termed as the National Capital Territory of Delhi. There are two reasons for this. First, a larger geographical boundary would imply a larger number of stakeholder institutions, increasing the project's complexity. the Delhi government's jurisdiction is limited to the city. Second, limiting the geographical coverage of the project to a smaller area within Delhi would mean easier monitoring and verification, but would require substantial re-calculation and probably primary survey for estimating the baselines and emissions savings. This would have implications for the project budget. In addition, the city's institutional structure is such that the jurisdiction of the agencies involved in inspection and maintenance is the entire city; so data and information is available at the city level. Essentially this would imply that only vehicles registered within the city of Delhi, hence governed by regulatory authorities in Delhi, would be covered in the project.

Proposed baseline methodology

Vehicular emissions for a given period may be viewed as the product of (1) emissions per unit of fuel, (2) fuel consumed per kilometre, and (3) total vehicle kilometres. The first two factors may be viewed as a composite variable, namely, emissions per kilometre, which varies from technology to technology; whereas the last factor, vehicle kilometres, can be further viewed as a product of the number of on-road vehicles times the effective distance covered by each mode.

Based on this generalisation, a baseline for the Delhi transport sector based on existing emissions, taking into account future expected changes including emission legislation, increase in demand, and improvements in technology has been estimated. It is assumed that the present trend of registration of vehicles adjusted with assumed attrition values for different modes and penetration of energy efficient modes would continue in Delhi, and that modal split pattern, and vehicle utilisation remain unchanged. The baseline incorporates improvements both by way of improvements in fuel efficiency due to better technology and emissions performance by way of increasingly stringent emissions standards. A detailed description of the methodology used to estimate the baseline is presented in Annex 1.

Operational lifetime and crediting period

The inspection centres being suggested as part of this project are expected to last 15 years. This is based on inputs provided by various equipment manufacturers on the life of the equipment proposed to be installed at the inspection centres.

The Marrakesh Accords specify the maximum crediting period during which a CDM project can earn CERs (certified emission reductions). Project proponents can choose either a ten-year or a seven-year crediting period. In the first option, it is assumed that the baseline chosen at the beginning of the project is unchanged for at least ten years, and the project can continue to earn CERs. In the second option, the project can earn CERs for more than ten years, provided the baseline is re-examined after seven years. If the baseline is shown to be still valid, or is updated to reflect the prevailing situation, then the project can be renewed for seven years at a time. In this option, CERs can be earned for up to 21 years.

For this project, a ten-year crediting period has been chosen This option is more favourable in terms of financial decision making, as the project partners can avoid the uncertainty associated with a changed baseline, and hence in expected CER revenue[a]

Reduction in GHG emissions due to the project activity

There is presently no regular fitness-checking programme for in-use private vehicles in India. Simple Pollution Under Control (PUC) checks were introduced in 1991 for all vehicles under Rule 116 of Central Motor Vehicle Rules, 1989. These privately run PUC centres carry out rudimentary emission tests, and do not monitor the fuel efficiency of in-use vehicles Commercial vehicles are required to undergo simple fitness checks in addition to PUC checks.

With the inefficient and primitive existing I&M set up, there are substantial benefits to be had from improved fuel efficiency of vehicles, through better enforcement of tail pipe emissions standards for in-use vehicles Further, a number of barriers exist, which prevent this regime from being implemented. These include.

- *Technology:*There is a large gap between the scientific basis of the existing inspection and maintenance scheme and that which can be envisaged in this initiative A lot of technological development would be necessary in the present regime. This would include the type of equipment and skills necessary for such a scheme
- *Infrastructure:*Based on technological requirements, strategies for augmentation of the inspection and maintenance infrastructure would have to be addressed as part of this initiative.
- *Policy:* Although policy statements emphasise the need for an effective inspection and maintenance regime, regulatory support is weak This would have to be addressed. In addition, policy support on the type of emissions and fuel efficiency standards to be targeted for in-use vehicles would be needed

An effective inspection regime for in-use vehicles, coupled with a penalty regime, is expected to result in improved vehicle maintenance. Thus, the performance of all vehicles would improve on all counts, including fuel efficiency This improvement would directly affect GHG emissions from the vehicle population, while at the same time improve the local air quality also. However, in absence of any data on fuel efficiency improvement across different range of vehicles due to inspection and maintenance in India, the emission estimates in the CDM project are presented as a range of potential improvements of fuel efficiency of 5% and 24% reported by Das et al. (2001) and Japan Automobile Research Institute (2001) respectively[b].

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[a] Annex I Parties can bank only 2.5% of the assigned amounts for future commitment periods

[b] JARI reports fuel efficiency improvements of 24% Das et al. (2001) report an improvement of only 5% in the US following the US EPA IM240 program.

It must be noted that the reported efficiency is assumed to be sustained for the entire project period, in the absence of any information on the longevity of these improvements. Thus, this analysis provides only an indication of the potential savings from the I&M regime and these savings would need to be re-established before any proposed CDM project.

Stakeholder comments

Potential stakeholders include the following.

- Research and development institutes, such as TERI[a], ARAI and Indian Oil Corporation (R&D Centre)
- The role of the private sector in the form of the automobile industry would be important, as they would provide managerial and financial support for such schemes. This would include after sales service for automobiles (garages and component manufacturers).
- Government sanction would be needed from the State Transport Authority, Government of National Capital Territory Delhi, and the Ministry of Road Transport and Highways, who regulate the transport sector The nodal agency for climate change activities in the Government of India is the MoEF (Ministry of Environment and Forests). In order to implement this option as a CDM project, clearance would need to be obtained from the MoEF for further development.

All these organisations were consulted at the stakeholder seminar on urban transport held in New Delhi in April 2002 (see above) A number of other stakeholders, from other government departments and research and NGOs were present at the workshop.

Inspection and maintenance was considered a relevant and desirable option by all stakeholders as even minor improvements in the I&M regime could result in substantial impacts given the primitive state of the present regime in India. The importance of this option was emphasised given the large number of in-use vehicles. In addition, it was felt that this would be a cost-effective measure. In the course of the presentation and the discussions that followed, the salient points that emerged are as follows:

- There is absence of initiative to take I&M forward, emphasising the additionalility of this initiative This was in part related to the issue of economic viability of I&M projects for private parties.
- Enforcement is missing, knowledge and skill levels are low, regulatory framework is weak and policy support is lacking. This would have implications for monitoring and verification discussed subsequently.

Monitoring plan

The monitoring and verification plan for the proposed CDM project is suggested in accordance with the defined baseline for the project and the project structure. The defined baseline for the project is the emission of GHG from the vehicles under business-as-usual.

GHG emissions from the fleet of vehicles will increase greatly in the absence of the proposed project. Every vehicle which is inspected and maintained in the proposed I&M centre, will lead to reduction of GHG emission . The following factors are important in determining the extent of GHG reduction from a given vehicle:

e) The design fuel efficiency of the vehicle and the expected fuel efficiency given the age of the vehicle, if the vehicle is maintained as per the present practices.
f) The improvement in the fuel efficiency of the vehicle due to checking and maintenance at the proposed I&M centre and the longevity of such improvement of efficiency.

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[a] TERI could develop the necessary scientific and institutional framework for the inspection and maintenance scheme, and advise on project development

Factor a) will be predetermined for a variety of sizes, makes, models and age of the vehicles. Factor b) will be predetermined for the range of vehicles The actual reduction achieved due to the project will be determined based on the two factors together, plus the actual number of visits by different types of vehicles to the proposed I& M centres

Costs and savings

Table 2 Summary of results, based on the CO_2 emissions and costs.

Project cost (US$ million)	94 36
NPV of project (US$ million)	-42 85
CO_2 savings (kilo tonnes)	2568-12325
Cost of CO_2 (US$ per tonne)	3.48-12 44
Impact of CDM on IRR (Low GHG reduction scenario)	-16% to -6%
Impact of CDM on IRR(High GHG reduction scenario)	-16% to -3%

As can be seen from the table, infusion of private capital could significantly influence the attractiveness of the project, raising the IRR from -16% to between -6% and -3% depending on the emission reduction scenario being considered.

Transport Demand Management option

A combined set of measures

This option discusses using a combination of three traffic management options in New Delhi. augmenting public transport, restricting use of personal vehicles and car-sharing[a].

As mentioned above, participants in the seminar in New Delhi on 22 April 2002 expressed the clear opinion that the transport field is too complex for only one option to have a real effect if implemented. Participants expressed clearly that a package of measures would be needed to reduce CO_2 emissions and improve up New Delhi's air quality. Therefore, a single option composed of three individual components was adopted as a second, longer-term, option. Because so little work has been done in this area, the costs/savings assessment presented here is made on the basis of the best available information and understanding of the issues. The assumptions which were used in the estimates work are open to debate· further work would be required to provide definitive figures.

A number of transport demand management (TDM) options were discussed at the seminar. There are two sets of reasons for why some of the initially promising options were discarded. Firstly, the greater the number of individual components, the more complicated the overall system, and the more difficult it is to measure and verify. This meant that the number of options in the cluster had to kept as low as possible. Secondly, each rejected option had an individual problem that caused it to be rejected[b].

The individual components

Augmenting public transport

Increases in the relative share of public transport[c] result in lower CO_2 emissions, improvements in the local environment and less congestion. Various New Delhi policy documents recommend that public transport attain a modal share of 75% of the total travel demand. A well-maintained bus service should displace passenger transport by cars and two-wheelers. providing more busses is therefore an important GHG mitigation opportunity. CO_2 reductions would emerge out of the following two factors.

- Fewer total vehicle kilometres travelled due to greater modal share for public transport
- Improved bus technology resulting in increased energy efficiency

A number of specific constraints apply to New Delhi[d].

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[a] There is a difference between car-sharing and car-pooling Car-sharing refers to private usage of a commonly provided fleet of cars and is much like short-term car hire. Car-pooling involves private vehicle ownership and efficient use of the vehicle (e.g four people driving to work each day in one car instead of in four separate cars).

[b] All traffic management options are by definition site-specific. By contrast, the other components of the 'cluster-option' are applicable city-wide. This, combined with the fact that traffic management options are difficult to monitor, meant these were unsuitable for inclusion. These include options such as NMT (non-motorised transport) infrastructure and priority to public transport which could be a powerful option, but would be extremely difficult to monitor and would require a site-specific baseline. In combination with the other options, it would simply be too complicated to be feasible.

[c] Public transport here has been defined to include buses and urban rail systems. Modes such as taxis, three wheelers, and rickshaws are classified as intermediate public transport modes

[d] In 1998, the Supreme Court of India gave a number of directions to the government aimed at reducing emissions from the transport sector. In effect, these directives required a city public bus fleet of 10000 buses and mandated that only buses running on CNG would be allowed. Supply side constraints include the availability of both busses and adequate quantity of fuel.

Restricting use of personal vehicles

Increasing transport's modal share requires restricting the use of personal vehicles, failing which CO_2 emissions are likely to increase with the introduction of new vehicles Focussing restriction schemes on personal transport modes would facilitate the shift to public transport, thus reducing total vehicle kilometres in New Delhi, leading in turn to lower fuel consumption and emissions.

The success of such initiatives in Singapore and other locations has generated interest amongst stakeholders in India. There is considerable eagerness to evaluate the effectiveness of such measures in congested areas in urban agglomerations in India. Empirical evidence suggests that the use of market based instruments to address external costs, such as those related to vehicle emissions, is more efficient than the use of command and control strategies. Thus the focus would be on strategies such as parking fees and congestion charges to reflect the scarcity value of road space, rather than banning the use of personal vehicles.

This part of the TDM option would restrict the use of personal vehicles in one congested area of New Delhi This would demonstrate benefits of the scheme and strengthen the case for replication elsewhere. It would involve strong stakeholder involvement on the basis of congestion and traffic density. Measures to restrict the use of personal vehicles would be identified. These could include congestion charges on the entry of private vehicles in delineated areas during peak hours, parking fees, and regulatory, administrative, and legislative changes that may be necessary to make the scheme work.

Car-sharing

Car-sharing is an increasingly popular concept in Europe as a mobility solution for private urban transport needs. It brings numerous advantages for both user and provider, as well as having environmental benefits. The company running a car-sharing scheme can be either for-profit or not-for-profit[a]. Swiss experience has shown it is better to have a dedicated, independent, company administering a car-sharing system.

An effective and far-reaching car-sharing system in New Delhi could have the triple benefit of lowering CO_2 emissions, reducing local air pollution and helping to reduce congestion It should provide a lower absolute number of vehicles than business-as-usual, with car-pooling replacing personal vehicles and reducing overall vehicle kilometres; made with lower-emission vehicles than presently on the road[b].

This part of the transport demand management option would involve starting a car-sharing scheme in New Delhi to provide a service which makes mobility affordable and helps attain access to goods and services, while eliminating the need to own a private vehicle[c] Concrete vehicle targets could be set, as could a target number of users. The financial outlay necessary and the energy and environment implications of the proposed car-sharing fleet would then be established It would require a comprehensive overview of the most appropriate organisational system and communication technology; and a comparative evaluation of the options based on their financial implications and emissions characteristics Co-operation with various stakeholders is highly desirable. These include public transport providers, local administration and private companies.

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[a] Organisations such as "Mobility Car Sharing" in Switzerland have found that car-sharing provision can be a profitable venture, while some German operators operate on a not-for-profit basis

[b] More information from http://www.carsharing.org

[c] An alternative would be to encourage individual companies to implement a work-based car-pooling scheme. This latter would have a more limited but more clearly-defined scope.

Fuel cell technology

Although not part of a transport demand option, the project partners decided to look at the effect of using fuel cell busses, given the international interest in fuel cells. It became clear that fuel cells will be too expensive an investment for too small a CO_2 emissions reduction gain. As a result, it does not make sense to include fuel cells as part of a project. Nevertheless, information on fuel cell busses is left in to provide more rounded information.

Barriers

The main barriers to the transport demand management option include.

- *Technology* Mass production of particular types of buses, such as low floor or CNG buses. Technology for charging schemes and managing car-sharing systems needs to be of a high standard
- *Infrastructure* Fuel availability for the bus fleet may be an issue if alternative technologies such as CNG are used. Some level of infrastructure development would be necessary to restrict personal vehicles. For car-sharing, the location of the depots is crucial the scheme must make cars easily accessible.
- *Policy* The Supreme Court of India has mandated CNG as the only fuel option for the bus fleet. There is little field experience with such technologies.
- *Organisation* Setting up a car-pooling scheme requires significant organisation.
- *Finance* Car-sharing requires initial capital in order to access staff and vehicles, there is a certain element of risk in setting up a scheme in New Delhi.
- *Technology* Experience has been that the most efficient way to implement and administer a car-sharing scheme would be with smart-cards. This requires a certain level of technological infrastructure which would need to be provided (the choice of technology is very important: chip-card readers, etc)
- *Psychology* For example, a car is prestigious: car-sharing tends to be less so.

Stakeholders

A range of stakeholders would need to be involved in the transport demand management option. All were represented at the New Delhi seminar and insisted on the need for a combined option. Stakeholders include:

- State Transport Authority, Government of National Capital Territory Delhi
- Delhi Transport Corporation
- The automobile manufacturing industry
- Private business interests for augmenting local manufacturing capacity or imports, either in terms of equity participation or by way of grants in return for emission credits
- The Delhi Traffic Police
- The Public Works Department
- Local municipal authorities: Municipal Corporation of Delhi, and New Delhi Municipal Corporation
- Employers with large workforces

International experience

Nothing of this kind has previously been undertaken, though some of the individual components have been contemplated.

There have been experiments in public transport, though none with a view to reducing CO_2 emissions or significantly increasing the public transport offer. A study, "Efforts Toward Sustainable Urban Transport and Clean Air in Surabaya, Indonesia", looks at the damaging effects of the increase in motorised-travel within the city and the challenges of

designing a sustainable urban transport policy. The study also offers technical solutions to accompany the policy (such as use of CNG buses and car engines), economic instruments (surcharge on gasoline, reform on annual vehicle taxation system that favoured the old, highly pollutant cars)

There are some bus projects internationally, though more to demonstrate new technology than to increase bus fleet sizes. For example, hydrogen fuel cell buses for urban transport in Brazil, designed to stimulate the development and utilisation of fuel cell buses by supporting a significant operational test of fuel cell buses in the greater São Paulo Metropolitan Area The project operated 8 fuel cell buses, with the aim of demonstrating fuel-cell technology. The preliminary evaluation indicated modest results due to the short time-frame, limited funding and limited capacities. In Egypt the focus is on electric and hybrid-electric bus technologies. A project by the Egyptian Environmental Affairs Agency is underway, aiming to demonstrate these technologies and strengthen the operational and infrastructural requirements for them to be used in the future. The GEF has also launched an initiative to develop fuel cell buses in India, in association with the local industry. There is clear stakeholder support for such an initiative, but again it is more technology testing at this stage than providing a serious number of new busses.

There has been some movement in restricting use of personal vehicles For example, raised fuel taxes, an area licensing fee and rigid parking controls Singapore has restricted traffic through its area licensing scheme for congested areas. The reduction in congestion in the city has been reflected in smoother movement of traffic, thus lowering fuel consumption and emissions. However, it must be noted that the traffic management regime in Singapore operates in a social, economic, and political environment that is very different from the one in India and the emphasis in this opportunity would have to be on identifying strategies and options that are relevant in the context of Delhi, and adapting these to suit Delhi's conditions. However, the initiatives have not been undertaken with CO_2 reduction in mind.

Car-sharing functions well in European countries like Switzerland, where they are a profitable business. However, there are no examples in developing countries; and the European examples were not set up specifically with CO_2 savings in mind.

Description of the project

Each individual option involves a series of trade-offs when implemented in isolation, so there might be greater benefits obtained from the synergies of several options being implemented together

The following individual options were selected for consideration as a combined project:

- Augmenting the New Delhi bus fleet by expanding the existing bus fleet from about 7,000 to 10,000 vehicles. It is assumed that all the new buses are fuelled by CNG, as required by a Supreme Court direction in 1998 Primary constraints would be the financial investment required, both in vehicle purchase and in developing a CNG supply infrastructure,
- Restricting the use of personal vehicles. The suggested means of achieving this could be either by prohibiting vehicles with excessive air pollutant emissions from the city or by charging fees for entry by personal vehicles to certain parts of the city;
- Car-sharing. This can be undertaken by specialist service companies, using high quality vehicles, and IT systems for organising the service and charging users (eg with smart-cards for the driver to have access to the vehicle). It would be a means of offering choices within the framework of improved public transport and restricted use of personal vehicles in the central area of the city.

In addition, the potential for fuel cell vehicles to meet the demand for personal transport in the long run was considered to be an important option to examine. It was felt that these three measures when combined together, with the possible inclusion of demonstration fuel-cell vehicles for the bus fleet or for the car-sharing fleet, represented the best combination of effectiveness and manageability as a CDM project. Combinations of measures hold out the prospect that positive effects can be achieved by means of one type of measure reinforcing or supporting another in changing the behaviour of transport users For example, if restricted parking controls are introduced into the CBD or other highly-trafficked areas, then their impact can be enhanced if there are viable alternative transport options available to travel to these areas, such as improved public transport or car-sharing facilities.

Costs/savings methodology

Data on the effectiveness and CO_2 reduction potential for most traffic management options, especially those in developing country applications, are very sparse. This point needs to be made clearly at the outset. Annex 3 presents the cost estimates and emissions data that have been assumed for present purposes.

The approach adopted for the investment costs/CO_2 savings analysis was to make use of an analytical framework developed for the World Bank[a], in which the carbon emissions from a particular transport sector are expressed as a function of total travel activity, modal shares, modal energy intensity of each mode and the carbon released per unit of energy of the fuels used in each mode. The interactions that occur as a result of implementing a combination of traffic management options can be assessed using an interaction matrix. This enables a basic qualitative analysis to be carried out on how the different transport policies can affect the various components of travel related emissions. It is also possible to include empirical information from other technical or modelling studies, which have analysed the effects of combined traffic management measures in different urban areas. Annexes 4 and 5 provide details of several European-based studies which were consulted for information. No relevant studies have been found which examine these issues in a developing country setting.

Ideally data would be available on the behavioural choices made by car drivers, their passengers and public transport users, and information on the preferences they have for different transport modes, travel demand patterns, journey types etc. For example, a transport network modelling technique could be used to examine the impact of different policy measures[b]. However, there is no equivalent model available for New Delhi and very little data exists on these factors in an Indian context; so the present figures are a best-guess estimate on the basis of existing information, using the World Bank's "interaction matrix" approach.

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[a] This is known as the ASIF approach, and is described more fully in "Transport and CO2 emissions: flexing the link – a path for the World Bank", World Bank Environment Department, September 1999.

[b] Network models represent travel demand by estimating the number of trips starting and ending in each "origin" and destination" zone of an urban area. Demographic, socio-economic and land-use factors are used to calibrate the model which usually contains several hundred zones. The model assigns trips to routes throughout the transport network, choosing between modes, and taking account of congestion delays and the waiting time for public transport.

Interaction Matrix

The interaction matrix between each of the traffic management options and the components of travel related emissions is shown in Table 3

Table 3: Interaction Matrix

Traffic management measure	Activity	Modal share	Vehicle energy intensity	Fuel mix
Augmenting New Delhi bus fleet (private operators)	Reduced total vehicle-km due to cars users shifting to bus	Increased modal share for public transport	Improved vehicle technology and increased energy efficiency	CNG offers better air quality benefits
Restricting use of personal vehicles	Significant restraint on car use, but depends on extent of costs, time of day, and effectiveness of enforcement	Favours travel modes with high passenger load factors (ie bus and taxi)	Little effect unless permits small vehicles selectively	Little effect unless cleaner fuels exempt
Car-sharing	Lower absolute number of vehicles and reduced total vehicle-km	Shifts from other travel modes	Little effect unless higher efficiency vehicles used	Little effect unless cleaner fuels used
Fuel-cell vehicles	Little direct effect	Little direct effect	Encourages improvement in vehicle energy efficiency	Potentially large effect[a]

These interactions indicate that the set of three traffic management measures can be mutually reinforcing and complementary[b] The use of fuel-cell vehicles can be seen as an additional feature of the combined project

CDM aspects of the combined options

The positive aspects of the proposed combined options project that may assist in putting it forward as a CDM project are as follows·

- Using a controlled fleet of vehicles – both busses and car-sharing vehicles – allows more reliable information on fuel used and kilometres travelled. Baseline calculation and monitoring data collection and analysis are made much easier in this situation;
- Sub-sector technical baselines can be estimated using base year emissions data along with projections of future emissions levels based on technological parameters of the type used in this report. However, this needs to be combined with a regional baseline which takes into account the entire local transport sector and allows for modal transfer and behavioural changes by car users,
- The proposed combined option includes elements of mode shifting, that is encouraging car users to travel by public transport instead. This shift does not affect the emissions per bus-kilometre, but rather the emissions per person-kilometre. Thus the baseline and monitoring need to be expressed in terms of CO_2 reduction per person-kilometre travelled rather than per vehicle-kilometre travelled. This means that the combined effects of the three measures can be aggregated into a single function to demonstrate the CO_2 reduction potential.

In general, the high levels of uncertainty in baseline determination and in projections of the emissions reduction impacts of a project are major obstacles to the success of transport

[a] Although there would be a relatively small number of busses in use, they would have a potentially large effect due to the refuelling infrastructure and investment that would be needed for these busses to operate.

[b] See also results from studies quoted in Annex 4,

CDM projects. There is very little information available on accurate baseline data and on the potential emissions reductions. Data collection on emissions from the many mobile sources involved is a particularly difficult issue[a].

Three main technical challenges should be considered:

1. historical and current data deficiencies, e.g. amounts of fuel used by transport, vehicle fuel efficiencies, kilometres travelled, types of trip purpose, types of road;
2. historical and current data uncertainty, since fuel consumption data collected under laboratory or test conditions may not reflect actual fuel consumption due to (e.g.) differing driving patterns, traffic conditions;
3. forecasting uncertainties, given that the transport sector is very complex.

Monitoring the impact of a transport project has similar problems, since it is extremely difficult to collect the necessary data. Transport projects can also lead to significant secondary effects, which are not readily accounted for. To be able to include these effects in the emissions reduction calculation there needs to be additional monitoring, thereby adding to the overhead costs. As a result, verification of CO_2 emission reductions would require considerable resources in terms of data collection, assessment and presentation of information in order to confirm the CDM benefits[b].

Assumptions

The assumptions underlying the combined project have been made as follows.

The bus fleet is augmented by 3,000 new CNG buses, delivered at the rate of 600 per year over a 5-year period from 2003 to 2008. These buses are operated by private companies, which offer chartered services, providing high quality travel that aims to compete with personal vehicles. A new CNG refuelling infrastructure is required: 10 new bus depots are built at a rate of 2 per year over the same period. Starting in 2003, traffic management measures would be introduced. Restricting the use of personal vehicles would be implemented by means of parking fees and congestion charges for central areas of the city. The scheme could be designed on a time-basis (e.g. during the morning and evening travel peaks), so that drivers are deterred from using their personal cars, and decide instead to use public transport or the car-sharing scheme. Park and ride facilities could be introduced as suitable locations in order to encourage the modal shift. The car-sharing scheme would be launched by a specialist service provider (which would itself be established by means of a suitable financial and operational method). These traffic management measures would be fully implemented by 2008.

The effects of these measures are assumed to be as follows:

- Increased availability of good quality, efficient public transport with air quality benefits encourages substitution or replacement of some car travel by bus use;
- Car drivers are deterred from travelling into the restricted area, leading to reduced numbers of passenger car movements, and modal transfer to public transport;
- Car drivers are also encouraged to switch to the car-sharing scheme, with good quality, efficient personal transport;
- Pilot schemes for fuel-cell vehicles would provide low carbon vehicle technology (if the hydrogen is produced from non-fossil sources).

[a] For a discussion on CDM issues in transport see "An initial view on methodologies for emission baselines: case study on transport", Deborah Salon, International Energy Agency, Paris, 2001.
[b] It would be worth examining how carbon financing from CDM projects can be attributed to other benefits of the combined options, such as reduced air pollution in the city, reduced traffic congestion etc. These benefits will accrue over a longer time frame than the accounting period that is used for CDM purposes.

Three scenarios are used in order to test the sensitivity of assumptions[a].

Scenario I. All the additional bus fleet capacity is fully taken up by car drivers and their passengers, who use the bus, thereby substituting car travel for bus travel 270,000 car journeys are replaced each day by these behavioural changes. CO_2 emission savings are obtained from the reductions in car travel There are also air quality benefits due to the use of CNG fuel in the additional buses. Total capital cost is estimated at $275M.

Scenario II. As for Scenario I, but personal travel by car users into the central area at peak times reduced due to the deterrent effect of access restrictions. It is assumed that 250,000 additional car users switch to public transport. In addition, 2,000 car owners switch to car-sharing by 2005, and 8,000 by 2010. Additional CO_2 emission savings are obtained due to shifts from cars to increased bus and MRTS patronage (including at non-peak times) Total capital cost is estimated at $330M.

Scenario III· As for Scenario II, but with 100 fuel cell vehicles introduced into the bus fleet. CO_2 emission savings are obtained due to fuel cell vehicle technology Total capital cost is estimated at $360M.

Costs, emissions and traffic data used in the calculations are shown in Annex 3[b]

Costs and savings

The CO_2 savings have been calculated for each of these scenarios, compared with the "business-as-usual" situation. Savings and costs have been calculated assuming a 10 year crediting period from 2003 to 2012 However, the time period for project development and uptake has been taken into account In all cases, it is assumed that the measures are fully implemented by 2008, with savings increasing linearly up to the maximum, and thereafter the maximum achieved in each year from 2008 onwards.

No account has been taken of any income from bus passengers or from parking fees: these fare-box monies are assumed to be equal to the operating and fuel costs for the additional buses and the traffic management measures, and therefore have a zero net effect on the project economics[c]. All capital costs are assumed to be incurred linearly over the period 2003-2008, and are discounted at 10%. See Annex 3 for further details. The results for each Scenario are listed in Table 4.

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[a] Other assumptions could be examined, for example if persons using non-motorised transport (NMT) were to use the additional buses in Scenario I, then fewer car journeys might be saved. If larger numbers of car drivers switch to public transport in Scenario II, then more car journeys might be saved. However for the purposes of this brief report, only one set of assumptions has been used

[b] A break-down of the CO_2 and cost savings associated with the add-on actions is not given, as the point of the exercise was to see how the various factors interact with each other. Some initial data was presented at the stakeholders' seminar in April 2002 in New Delhi.

[c] In particular, it has not been possible to assess the costs of providing hydrogen fuel for fuel cell vehicles. The calculations assume that hydrogen comes from renewable energy sources (and is therefore zero carbon), but no account has been taken of the additional costs of developing renewable systems in India. US estimates range from $20-40/GJ for hydrogen production costs from wind power, compared with $3-$5/GJ for diesel fuel

Table 4: Results of calculations

Scenario	Actions	CO_2 saving (ktonne) in 2008	Cumulative CO_2 saving (ktonne) over period 2003-2012	Discounted capital costs ($M)	Discounted cost/tonne CO_2 saved over 2003-2012
I	Car users switch from gasoline vehicles to CNG buses	1015	7105	$226	$32
II	I + increased bus and MRTS use in non-peak times plus car-sharing	1440	10080	$270	$27
III	II + use of fuel cell vehicles	1450	10150	$295	$29

The most cost-effective result is obtained for Scenario II when all the traffic management measures combine together to stimulate modal shifts and behavioural change. Fuel cell vehicles (Scenario III) reduce the cost-effectiveness of this combination, due to the high capital costs associated with them, and using fuel cells is therefore clearly not a good choice from a financial perspective[a]. These results are broad estimates only, due to the limited nature of data availability, but are indicative.

Discussion

Greenhouse gas mitigation measures in the transport sector are generally more complex than measures in industry or buildings. Traffic management measures aimed at improving air quality or reducing traffic congestion in urban areas have usually taken priority over CO_2 reduction measures in the transport sector. Hence allocating the costs of traffic management measures to CO_2 emissions reduction is not necessarily the right starting point for CDM project analysis since other social and economic benefits can be obtained alongside CO_2 reductions.

If all the costs associated with the combined measures are allocated to the CDM project, then the cost-effectiveness of the project is poor, unless the combined measures can stimulate significant modal shifts to public transport and/or car-sharing, together with behavioural changes in travel patterns. Augmenting public transport with CNG buses has the potential for saving CO_2 emissions, but this is expensive given the large investment necessary in building up the required bus fleet and refuelling infrastructure. CNG buses offer no CO_2 emissions benefits on a "well to wheels" basis compared with diesel buses[b].

[a] Fuel cell buses are not likely to have a major presence in the market before 2010. they were included in this paper, however, as early demonstration vehicles could be available.

[b] It is worth noting that the adoption of new vehicle technologies in the form of fuel cell cars and buses does not offer any additional benefit, since fuel cell vehicles also have high costs and the hydrogen must come from renewable sources for there to be a significant CO_2 reduction

Conclusion

The two options described in this report are the result of a process of research and consultation. There is a clear difference in costs and quality of available information between the two options, due to their differing nature. Stakeholders have shown a great deal of enthusiasm for both.

Inspection & Maintenance is essentially a short-term option which would provide immediate air quality benefits and CO_2 reductions. Transport Demand Management, on the other hand, is a longer-term and more ambitious option

Real changes to CO_2 emissions in the transport sector will need to go beyond technology, as has been found in Europe. In this regard it is interesting to see that it does seem possible, even at this early stage, that the transport demand option could engage in a CDM project which uses good technology as a base to avoid moving towards those transport priorities which are in evidence in developed countries, and which have led to thoroughly unsustainable development patterns. Such a development would be most heartening in moving towards sustainable transportation worldwide.

This has been an innovative research project, at the cutting edge of developing thinking on Clean Development Mechanism projects in the transport sector. It is to be expected that both the contents and the process followed in the project will provide vision and leadership in this area. It is to be hoped that one or both of the options explored in this initial research project is taken further, possibly by a conglomeration of partners.

Annex 1
EMISSIONS SAVINGS THROUGH INSPECTION AND MAINTENANCE IN DELHI

The specific model for estimating transport energy demand and emissions under alternate scenarios in Delhi has been developed for reference years 1990, 2000, 2005, 2010, and 2015. The vehicle kilometres are estimated using Equations (1) and (2).

$$D_t = \sum V_{kt}^{*} \times U_k \qquad .. (1)$$

$$V_{kt} = d \pm b_k \times S_t \qquad ... (2)$$

where D is the total vehicle kilometres, V is the number of registered motorised passenger vehicles and V* is the number of vehicles in use[a]. U denotes the average vehicle utilisation expressed in km/vehicle. Index k denotes the major modes and t is the time period, with t = (n+1) - base year and n, the reference year. The coefficients in Equation (2) are obtained by the ordinary least square method regressing the number of vehicles registered in Delhi on the State Domestic Product. Subsequently the share of total vehicle kilometres by personal, intermediate and public modes was estimated using Equation (1). Finally, the classified modes are further disaggregated into different categories of vehicles along with their model year/technologies and alternative fuels that are either in use (obtained from the sales records) or are likely to be introduced in near future. The average energy intensity for each technology considered is then used to estimate the annual fuel demand. The complete mathematical structure is given in Equation (3).

$$F_{kit} = D_t \times Z_{kt} \times E_{kt} \qquad ... (3)$$

where F is the annual fuel demand expressed in kilograms of oil equivalent (kgoe) and Z denotes the percentage share of total passenger travel demand by different modes and their respective technologies. E denotes the average energy intensity expressed in kgoe/km. Index i denotes the type of technology under a given mode k. Total energy demand is obtained by aggregating fuel demand across different modes and technologies. Similarly, annual emissions of each pollutant, denoted by j, is estimated by using Equation (4).

$$P_{jkit} = F_{kit} \times Y_{jkit} \qquad ... (4)$$

where P denotes emissions expressed in tonnes and Y the emission factors expressed in mass of pollutants emitted per unit of fuel burnt (g/kg). Total annual emissions of a pollutant can be obtained by aggregating the emission values across different modes and their technologies. Table 5 gives the various components in the framework.

Table 5 Table structure for urban transport energy environment analysis

Mode (%)	Vehicle Type (%)	Energy efficiency (Gj/km)	Emission factor (g/kg)
Personal Modes	2Wh · 2Stroke	Petrol	CO
	2Wh : 4Stroke	Petrol	HC
	Car/Jeep	Petrol	SO_2
	Car/Jeep	Diesel	NO_x
	Car/Jeep	CNG	PM
IPT Modes	3 Wh. 2 Stroke	Petrol	CO_2
	3 Wh. 4 Stroke	Petrol	

[a] The information on the number of vehicles in use is not available in Delhi – the only information that is available is the number of vehicles that have been registered over time. To obtain the number of vehicles in use in the city, the number of vehicles registered has been adjusted with appropriate attrition factor for each vehicle type. This has been done using appropriate age limits for each vehicle category. The detailed assumptions on the attrition factors are discussed in the following sections.

	3 Wh	CNG
	Taxi	Petrol
	Taxi	Diesel
	Taxi	CNG
Public Modes	Standard Bus	Diesel
	Standard Bus	CNG

Equation (2) is used to extrapolate the future growth of motor vehicle registration in Delhi up to the year 2015 based on the relationship between the ownership of vehicles and state domestic product using the regression coefficients presented in Table 5. The estimated numbers of vehicles of different categories likely to be registered in Delhi (following the current trends) over the next 13 years are presented in Table 6

Table 6 Estimated regression coefficients

Mode	Intercept	Total net SDP at 1980/81 prices (Rs)	R^2
Scooters/motorcycles	-244108.2	2.43	0.96
Cars/jeeps	-115668.6	0 91	0 96
Autorickshaws	-265.8	0.09	0.91
Taxis	2969 2	0 01	0 97
Buses	386 6	0.03	0 97

Table 7 Projected numbers of registered vehicles in Delhi (thousands)

Year	Scooters/motor cycles	Cars/jeeps	Autorickshaws	Taxis	Buses
2000	2472	902	108	181	38
2005	3621	1333	154	246	55
2010	5256	1945	219	337	78
2015	7582	2817	311	467	110

In the absence of any data on the number of vehicles retiring from road, the registration data of different categories of vehicles are adjusted with the age limit of autorickshaws, taxis, buses and light commercial goods vehicles as per the Supreme Court directives[a] whereas it is assumed that personal vehicles (scooters, motorcycles, cars and jeeps) would last for 15 years as there are no such directives.

Table 8 Maximum ages (years) of different categories of vehicles

Scooters/motor-cycles	Cars/jeeps	Autorickshaws	Taxis	Buses
15	15	10	10	8

The projected figures of registered vehicles presented in Table 7 are adjusted with the attrition values presented in Table 8 to obtain the number of vehicles *in use* for a given mode in a given year For instance, the number of two-wheelers on road in 2000 would be equal to the difference between the extrapolated number of two-wheelers in 2000 and the number of registered two-wheelers in 1985. Table 9 gives the estimated number of vehicles in use between 2000 and 2015.

[a] All public sector buses older than 8 years must be scrapped; all pre-1990 taxis and autorickshaws must be replaced as on 2000. Thus, the maximum age of buses is 8 years, for taxis and three wheelers is 10 years, and for personal vehicles is 15 years.

Table 9 Motor vehicles (1000s) on road after adjusted with attrition values

Year	Scooters/motor cycles	Cars/jeeps	Autorickshaws	Taxis	Buses
2000	1725	699	46	8	16
2005	2326	905	79	12	25
2010	3514	1311	111	16	33
2015	4911	1841	158	22	47

In the absence of any city specific data on vehicle utilisation of different type of vehicles, the average kilometres per vehicle per day by different categories of passenger vehicles have been taken from a countrywide study (ENCON 1987) [a] to estimate the vehicle kilometres in Delhi according to equation (1).

Table 10 Average load factor in different modes

Mode	Km/vehicle/day
Scooters/motorcycles	13.5
Cars/jeeps	120
Autorickshaws	27
Taxis	85
Buses	186

In terms of fuel efficiencies of vehicles, there are no limitations to the increased use of new technologies In view of the advancement in engine technologies through continuous R&D efforts by the Indian automobile industries, it appears that each category of vehicle/fuel combination plying on Indian roads today will constantly achieve fuel efficiency improvements. Based on a thorough literature review of fuel efficiency values of different categories of vehicles in the past and present, it is assumed that over the 25-year period (1990-2015), the potential scope of fuel efficiency improvement would vary for different type of vehicles. The next table gives the estimated improvement in fuel efficiency values for different categories of Indian vehicles during the period.

Table 11 Estimated improvements in fuel efficiency across modes, 1990-2015

Mode· technology: fuel	Unit	1990	2000	2005	2010	2015	Efficiency gain (%)
2-wheeler, 2-stroke. petrol	Km/litre	44.44	45 77	46 44	47.11	47 56	7%
2-wheeler, 4-stroke· petrol	Km/ litre	65 00	66 95	67 60	68 25	68 90	6%
Car: petrol	Km/ litre	9.43	10 37	10 85	11 32	12 26	30%
Car.diesel	Km/ litre	8.86	9.92	10.28	10 63	11.52	30%
Car. CNG	Km/m^3	-	14.40	15 12	15.84	16 20	13%
3-wheeler, 2-stroke· petrol	Km/ litre	20 41	22 04	22.76	23 47	23.98	17%
3-wheeler, 4-stroke petrol	Km/ litre	-	23.00	24.15	25.30	25.65	12%
3-wheeler, CNG	Km/m^3	-	25.00	26.25	27.50	28 19	13%
Taxi: gasoline	Km/ litre	9.43	10 37	10.85	11.32	12.26	30%
Taxi: diesel	Km/ litre	8.86	9.92	10.28	10.63	11 52	30%
Taxi· CNG	Km/m^3	-	14 40	15.12	15.84	16 20	13%
Bus: diesel	Km/ litre	3.30	3 40	3.49	3.57	3.61	9%
Bus: CNG	Km/m^3	-	3.40	3.49	3.57	3.61	6%

[a] ENCON, 1987. Estimation of total road transport freight and passenger movement in India. Engineering Consultants Private Limited, New Delhi.

Source. IIP, 1994, Bose, 1998, Auto India, 1999, Ogden et al., 1999[a]

The mass (exhaust) emission standards[b] for new vehicles in the country were first notified on 5 February 1990 and became effective on 1 April 1991. These were revised and made more stringent from 1 April 1996 and thereafter Bharat Stage I and Bharat Stage II (Equivalent to Euro I and II) emission standards for different category of vehicles were announced Proposals for norms similar to Euro III and IV are in pipeline. To conform to the stringent emissions standards, it is becoming imperative that fuel specifications and engine technologies go hand in hand

Emission factors of CO, HC, PM and NO_x have been compiled for different range of vehicles (along with their fuel efficiency values) over different time horizons. Table 13 also provides the mass emission factors of CO_2 This is independently estimated by multiplying the following parameters· (1) average carbon content in the fuel (by weight), (2) specific gravity of the fuel, (3) percent of fuel burnt, which depends on the engine technology, (4) total atomic weight of CO_2 divided by atomic weight of C. It is assumed that, on an average, 98-99% of the fuel is burnt. Table 12 provides the carbon content in the fuels along with their specific gravity.

Table 12 Carbon content and specific gravity of different fuels

Characteristics	Petrol	Diesel	Propane	CNG
Composition, weight % C	84 85	86.11	66.1	82
Specific gravity, 60° F/60° F	0.7008	0 8263	0 744	0 508

Source. www technocarb com/natgasproperties html

Table 13 Emission factors

Category	Year	CO(gm/km)	HC (gm/km)	NOx (gm/km)	PM (gm/km)	CO_2 (gm/km)[c]
2 wh 2 str	<1990	6 50	3.90	0.03	0.23	36.80
	1991-1995	6 50	3 90	0 03	0.23	36 40
	1996-2000	4.00	3.30	0 06	0.10	36 10
	2001-2005	2 20	2 13	0 07	0 05	35.40
	2006-2010	1 40	1 32	0 08	0.05	35.00
2 wh 4 str	<1990	3 00	0 80	0 31	0 07	32 90
	1991-1995	3 00	0 80	0 31	0 07	32 90
	1996-2000	2 60	0.70	0 30	0 06	32 20
	2001-2005	2 20	0 70	0 30	0 05	31 90
	2006-2010	1.40	0 70	0 30	0 05	31 60
3 wh 2 str	<1990	14 00	8 30	0 05	0 35	80 12
	1991-1995	14 00	8.30	0 05	0 35	77 04
	1996-2000	8 60	7 00	0 09	0 15	74.18
	2001-2005	4 30	2.05	0 11	0 08	72.84
	2006-2010	2 45	0 75	0.12	0 08	71 53
3 wh 4 str	<1990	-	-	-	-	-
	1991-1995	-	-	-	-	-
	1996-2000	-	-	-	-	-

[a] IIP, 1994. Vehicle Emissions and Control Perspectives in India: A State of the Art Report. Indian Institute of Petroleum, Dehradun Auto India 1999. CNG for a Better Tomorrow, August Ogden JM, Margaret MM, and Krentz TG, 1999. Comparison of Hydrogen, Methanol and Gasoline as Fuels for Fuel-Cell Vehicles: Implications for Vehicle Design and Infrastructure Development. Journal of Power Sources, 79(2)·143-168.
[b] Mass emission standards refer to g/km of criteria pollutants (namely, CO, HC, NO_x and PM) emitted by a vehicle during mass emission tests conducted under specified driving conditions.
[c] Estimated

	2001-2005	2 20	0.70	0 30	0.08	92.90
	2006-2010	1 40	0 70	0.30	0.08	86.02
3 wh. CNG	<1990	-	-	-	-	-
	1991-1995	-	-	-	-	-
	1996-2000	2 46	0 09	0 07	0 03	50 91
	2001-2005	1 23	0 03	0.09	0 02	47.73
	2006-2010	0 70	0.01	0 10	0.02	43.64
Car petrol	<1990	9 80	1 70	1 80	0 06	226.59
	1991-1995	9.80	1 70	1 80	0 06	217.87
	1996-2000	2 72	0.41	0 56	0.05	205 99
	2001-2005	1 98	0 25	0 20	0.03	200.52
	2006-2010	1 39	0.15	0.12	0 02	192.02
Car diesel	<1990	7 30	0 37	2.77	0 84	291 52
	1991-1995	7.30	0.37	2.77	0.84	280 31
	1996-2000	1.20	0 37	0.69	0.42	269.92
	2001-2005	0.90	0 13	0 50	0.07	255.72
	2006-2010	0.58	0.05	0.45	0 05	247.05
Bus diesel	<1990	5 50	1 78	19 00	3.00	782.68
	1991-1995	5 50	1.78	19 00	3.00	778.79
	1996-2000	4 50	1 21	16.80	1 60	771.07
	2001-2005	3.60	0 87	12 00	0 56	745 25
	2006-2010	3 20	0 87	11.00	0 24	741.70
Bus CNG	<1990	-	-	-	-	-
	1991-1995	-	-	-	-	-
	1996-2000	1 80	3 01	9 90	0 05	462.84
	2001-2005	0.72	3.01	9 90	0 05	445.04
	2006-2010	0.64	3 01	9.90	0.05	442 91

Source· CPCB 2000, Bose 2000, TERI database[a]

Table 14 summarises the estimated emissions of CO_2 and the critical pollutants corresponding to the reference years.

Table 14 Annual emissions under alternative scenarios (1000 tons)

	2000	2005	2010	2015
Baseline				
CO	121	95	71	73
HC	47	40	39	43
Nox	14	13	31	38
PM	4	3	3	2
CO_2	2266	2774	4769	5994
Inspection & maintenance for the entire vehicle fleet				
CO	121	72-90	54-68	55-69
HC	47	30-38	29-37	33-41
Nox	14	10-12	24-30	29-36
PM	4	2-3	~2	~2
CO_2	2266	2108-2635	3624-4530	4556-5695

The rate of increase of CO_2 emissions is more than 2 5 times over the period of 15 years in the baseline. In the case of criteria pollutants, the emission loading of CO, HC, NO_x, and PM in the baseline scenario shows a steep decline between 2000 and 2010. This is mainly due to the introduction of progressively stringent emission norms and penetration

[a] Bose 2000. Urban Transport, Energy and Environment. A Case of Delhi. Institute of Transportation Studies. University of California, Davis. 2000

of advanced vehicular technology This trend would however reverse beyond 2010 for all pollutants considered in our analysis. The rapid growth in travel demand beyond 2010 would offset the improvement in emission characteristics of new vehicles due to improved technologies with cleaner fuels

Annex 2
INVESTMENT COSTS FOR INSPECTION & MAINTENANCE OPTION

Cost estimates

The cost estimates for all options have been prepared for a 10 year project period, 2005 to 2015, given that this is the maximum emissions crediting period for a CDM project without revising the baseline[a]. The investment was assumed to take place at two time points, 2005 and 2010, instead of just once at the beginning of the project. The discount rate for this projects was assumed 12%. All calculations have been carried out assuming an exchange rate of 1 US dollar equals 50 Indian Rupees.

Costs and revenues

Only the cost of equipment for emissions testing has been taken into account for setting up a vehicle inspection centre; equipment for safety and roadworthiness tests has not been taken into account. The following are the cost components that have been considered (Table 15).

Table 15 Costs for various equipments for inspection centres

Category	Requirement	Cost of equipment (US$)
Emission test	Gasoline (4-gas analyser)	8,000
	Diesel (Opacity meter)	10,000
Land and building per centre	4000 ft^2 @ US$80 per ft^2	320,000
Manpower	2 persons @ US$ 300 per month	72,000
Operating cost of equipment	@ 6% of capital cost	
	Gasoline	480
	Diesel	600

The configuration of the emission testing equipment at inspection centres for the following category of vehicles are presented in Table 16. Costs components such as land and building, labor, and operating cost of equipment are common to all categories of vehicle testing centres

- 2 wheelers / 3 Wheelers
- 3 ton vehicle (cars/jeeps)
- 10 to 13 ton vehicle (buses)

Table 16 Configuration of various types of emission testing equipment

Category	Components
2-3 Wheelers	Gasoline (4-gas analyser)
4 Wheelers	Gasoline (4-gas analyser) and Diesel (Opacity meter)
Buses	Diesel (Opacity meter)

In addition, revenue streams were taken into account while estimating the net present value of the project at the rate of US$ 2 per vehicle per year. This is equal to the present rates for the existing inspection system in the city, the PUC regime described earlier in the report (US$0.5 per vehicle every three months).

Capacity of an inspection centre

The average capacity of the centre has been worked out assuming how much time it would take to inspect each vehicle based on a suggested frequency of the test. The actual figures might be different depending on factors like type of vehicle, skilled labour available infrastructure available, layout of the centre etc.

[a] Marrakesh Accords Decision 17/CP.7

Table 17 Proposed frequency for vehicle inspection

Vehicle Types	Frequency		
	<3 years	3-9 years	>9 years
Private vehicles			
Motorcycles & scooters	Biennially	Biennially	Annually
Cars / Jeeps	NA	Biennially	Annually
Commercial vehicles			
Taxis / Auto	Annually	Annually	Annually
Buses	Annually	Annually	Annually

The number of total vehicles that a centre can inspect in a year has been estimated for a two-lane centre The capacity has been worked assuming that it would take 20-30 minutes to inspect a vehicle and that a centre would work for 8 hours a day for 6 days in a week. The capacity of an inspection centre for different types of vehicles is given in Table 18 In addition, the number of test centres required to cater to the demand for the following five years is also presented. For instance, in the period 2010 to 2015, 189 two-wheeler test centres would be required.

Table 18 Capacity of a Vehicle inspection centre

Vehicle type	Capacity of centre (Vehicles/ year)	Number of test centres	
		2005-2010	2010-2015
Two Wheeler	26000	135	189
Three wheeler	21000	3	4
Car	17000	63	89
Bus	14000	2	3

Investment estimates

Based on the above cost inputs, the configuration of each type of test centre, and number of test centres required for each vehicle category, the investment estimates are presented in Table 19

Table 19 Investment estimates for the project

Vehicle type	Investment per centre (US$ million)	Total investment (US$ million)	
		2005	2010
Two Wheeler	0.33	44.33	17.63
Three wheeler	0.34	0.98	0.30
Car	0.33	21.38	8.63
Bus	0.33	0.78	0.33

ANNEX 3
COST ESTIMATES, EMISSIONS AND TRAVEL DATA, TRANSPORT DEMAND MANAGEMENT OPTION

Calculation methods

Table 20 presents estimates of the "well to wheels" greenhouse gas emissions for each travel mode and technology in 2000 and in 2020. They assume adoption of existing and state-of-the-art efficiency innovations[a]. Data take into account, amongst others, energy efficiency of each fuel in internal combustion engines, refining and other upstream energy requirements for gasoline and diesel fuels, compression energy requirements for CNG, and processing and transportation of natural gas. Note. CNG buses do not show GHG emission benefits compared with diesel buses on a well to wheels basis.

Table 20: Greenhouse gas emissions for vehicles and fuels in Delhi[b]

Technology	2000	2020
	GHG g/vehicle-km	**GHG g/vehicle-km**
Gasoline car	293	265
Diesel car	172	162
Diesel bus	963	975
CNG bus	1050	970

Table 21 lists the cost estimates that have been assumed for the traffic management measures within the combined option

Table 21: Cost estimates[c]

Traffic management measure	Major cost elements	Estimated total capital costs by 2008
Augmentation of public transport by 3,000 new CNG fuelled buses and 10 new CNG depots	New CNG bus $75,000 Fuel infrastructure $5M per depot. Provision of park and ride facilities at suitable locations. Vehicle maintenance.	$275M
Restricting the use of personal vehicles	Access restriction equipment, parking controls, and traffic management/parking facilities around the restricted area	$10M
Car-sharing scheme with 8,000 vehicles	Purchase of vehicles for the car fleet ($5,000 each), systems set-up, publicity, operational management, vehicle maintenance	$45M
Fuel cell demonstration programme, involving up to 100 buses	Fuel cell vehicle current cost $1M, assume a 80% reduction with volume production by2008. Infrastructure cost for hydrogen supply network $10M Vehicle maintenance, project management	$30M

[a] Source. "Transportation in developing countries. Greenhouse gas scenarios for Delhi, India", Pew Centre on Global Climate Change, May 2001.

[b] CO2 Data for this table is from the Pew Centre study of transport in Delhi. There could be advances in technology and improvements in vehicle efficiency and therefore in CO2 emissions over the period to 2020, particularly in US and EU vehicle technology. However, these improvements are unlikely to be transferred directly to the vehicle sector in India· there is not presently any evidence that direct technology transfer has happened to India with the US/EU technologies developed over the last 10-15 years. In any event, a time lag for market uptake is inevitable, so a reasonable assumption is that the actual improvements will be marginal over the period 2003-2012. In the longer term there might be benefits from improved vehicle technology, but these are outside the remit of this paper.

[c] Data sources – "Sustainable transport. New insights from IEA's worldwide transit study", L Fulton, COP7 Marrakesh, 2001; Author's estimates.

The additional cost per bus is assumed as $200 000. This may be somewhat optimistic, but it follows estimates from a UNDP-GEF Fuel Cell Bus workshop (April 2000), and from the IEA study referenced earlier. The range of additional capital costs was between $1M and $300k (worldwide volume production of 1,000 vehicles), and compares with a base price of around $100k for a high specification new diesel bus It made sense to agree with the assumption that volume production would give capital cost reductions for fuel cell buses, given other worldwide interests in procuring fuel cell buses (e g. in the UK).

Table 22 lists the travel data for buses and cars used in the calculations[a]

Table 22: Travel data

	Average occupancy	Average daily journey length (km)
Bus	50 (peak time)	215
Car	2 7	45

On the basis of passenger-km travelled, one bus replaces 90 car journeys per day, and it is assumed that this applies 365 days per year.

Calculation Methods

Scenario I

CO_2 savings in 2008 are estimated from the difference between

(1) the emissions from 3000 CNG buses operating over 215 km/day for 365 days/year, and

(2) the emissions from 270,000 gasoline cars operating over 45 km/day for 365 days/year

Net savings = 1015 ktonne CO_2 in 2008

Scenario II

CO_2 savings in 2008 are estimated from the savings achieved in Scenario I plus the savings from car users who are deterred from travel and switch to non-peak bus (or MRTS) use or use car-share. The Scenario assumes 250,000 gasoline car users switch (equivalent to 92,600 cars) and avoid travelling by car for 45 km/day for 365 days/year.
Net saving = 1015 + 425 = 1440 ktonne CO_2

Scenario III

100 fuel cell buses with zero CO_2 emissions replace 100 diesel buses operating over 215 km/day for 365 days/year. In this Scenario, car-sharing as an additional marginal activity is assumed to have zero net effect on CO_2 emissions[b].
Net saving = 8 ktonne CO_2 (rounded to 10 ktonne for the calculation).

Project implementation

In all cases, the projects are assumed to be implemented over the period 2003-2008. The cumulative CO_2 savings are calculated assuming that savings increase linearly from 2003 to 2008, and remain at the 2008 level thereafter until 2012. The capital costs are incurred in a linear manner over the period 2003 to 2008, and are discounted at 10%.

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[a] Data sources "Urban transport and potential mitigation options for Delhi", TERI Report 2001UT43, April 2002, "Transportation in developing countries. Greenhouse gas scenarios for Delhi, India", Pew Centre on Global Climate Change, May 2001.

[b] For a more detailed account of car-sharing and CDM, see "An initial view on methodologies for emission baselines. case study on transport", Deborah Salon, International Energy Agency, Paris, 2001.

ANNEX 4
EFFECTS OF COMBINED MEASURES IN OTHER STUDIES

This Annex presents information from other technical and modelling studies which have examined the effects of combined traffic management measures. Only data from EU studies have been given, since there are few studies of a similar nature in developing countries. The actual impacts of these measures on reducing emissions are unevenly documented and there is no clear consistency in reporting results or in the analytical treatments. Costs are often not included in the studies, and in many cases, information is available only on the impact of traffic indicators such as vehicle-kilometres rather than CO_2 emissions. In particular, it has not been possible to identify studies where costs have been expressed per tonne of avoided CO_2, or attributed to specific CO_2 savings.

Randstad region, Netherlands

Modelling work was carried out to estimate the impact of different policy measures on traffic and hence on CO_2 emissions in the Netherlands[a]. The model represented the transport network in the Randstad region by means of over 700 origin- and destination-zones Table 23 shows the effects of various measures combined into packages (CO_2 index = 100 for the "business as usual" situation).

Table 23: Combinations of Policy Measures in the Randstad

Description	CO_2 index
Parking controls (higher parking fees and improved public transport)	94
Price policy (fuel price increase, road pricing and parking fees plus improved public transport)	83
Do-nothing (no investment in roads but improved public transport)	95
Meet-demand (invest in roads to meet demand and improve public transport)	104

Economic Evaluation of Emissions Reductions in Transport in the EU

This study considered options to reduce greenhouse gas emissions from transport by means of a bottom up approach[b]. The study included information generated by the European Commission's CANTIQUE project, which drew on over 20 traffic modelling studies across Europe to assess the effectiveness and costs of various measures. Some data are available from these studies on CO_2 emissions of various combinations of traffic management measures, and these are listed in Table 24.

Table 24: Combinations of Policy Measures in some EU cities

Description	CO_2 index
Restricted access to selected zones and traffic reduction actions (London)	92
Financial incentives and awareness campaigns (West Germany)	96
Traffic control systems and public transport (Stuttgart)	95
Access control and parking pricing (Thessaloniki)	95

[a] "Transport Policy, Traffic Management, Energy and the Environment", NOVEM report for the International Energy Agency, 1992.
[b] "Economic Evaluation of Emissions Reductions in the Transport Sector in the EU", AEA Technology et al a study for DG Environment of the European Commission, March 2001.

ANNEX 5
CONGESTION CHARGING IN CENTRAL LONDON [a]

This Annex presents some capital and operating costs data for the proposed congestion charging scheme in central London. Congestion charging in London is scheduled to start early in 2003. It will only apply in central London where traffic congestion is at its worst. The aim is to reduce the volume of traffic – particularly personal vehicles – travelling into and through the centre of the city

Motorists are to be charged £5 (about $8) a day to drive within the central zone (7am to 6.30pm only), Mondays to Fridays. There will be no charge on public holidays. Drivers using a vehicle in the central zone will pay the charge, either in advance or on the day. The registration numbers of these vehicles will be entered into a database Drivers will be able to pay the charge on a daily, weekly, monthly or annual basis by telephone, post, internet or at retail outlets. They will not be required to display a licence.

The number plates of vehicles entering or moving within the central zone will be observed by a network of fixed and mobile cameras. There will be no toll booths, gantries or barriers; drivers will not have to stop The number plates collected by the cameras will then be checked against the registration numbers of those who have paid. The registered keeper of any vehicle identified within the central zone without the congestion charge having been paid (unless exempt/discounted) will be liable to a penalty charge. Exempt vehicles will include alternatively fuelled vehicles such as those operating on LPG, CNG and electric batteries. It is expected that an additional 220 double-decker buses will be needed for the London Transport bus fleet to accommodate the increased demand for travel by public transport.

The start-up costs of the scheme are estimated to be:

- £80M for scheme design, systems set-up, cameras, enforcement infrastructure, project management, computer systems and monitoring
- £70M for traffic management measures at the scheme boundary and elsewhere

Operational costs are estimated to be about £70M per year, and direct revenues from the scheme are estimated to be around £225M per year. These revenues are intended to be recycled into improvements in public transport provision in London.

The cost-benefit analysis, taking into account benefits in reduced travel times for cars, goods vehicles, and buses, air quality improvements, accident reductions etc, gives a total benefit over the first 10 years of over £1200M No calculations have been presented on the potential CO_2 emissions reduction benefits of the congestion charging scheme.

There would be many differences in New Delhi from the proposed London scheme. For the purposes of this report, however, the cost in New Delhi of a basic restricted access scheme with some of London's features is assumed to be around $10M

[a] Source Transport for London report on Congestion Charging, February 2002